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Pre-Play Communication with Forgone Costly Messages: Experimental Evidence on Forward Induction

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Pre-Play Communication with Forgone Costly Messages: Experimental Evidence on Forward Induction[*]

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We study communication in a two-player coordination game with Pareto-ranked equilibria. Prior research demonstrates that efficient coordination is difficult without communication but obtains regularly with (mandatory) costless pre-play messages. In a laboratory experiment, we modify communication by making the sending of messages optional and costly. Even small costs dramatically reduce message use, but efficient coordination of actions occurs with similar frequency to that observed under costless communication. Our results can be accounted for by Govindan and Wilson's formalization of forward induction (GW-FI), which selects, among the pure-strategy equilibrium outcomes, the one in which efficiency is achieved without communication. Consistent with the introspective character of GW-FI, the fraction of players who achieve efficient coordination by forgoing the use of reasonably costly optional messages is substantial from the first period, is remarkably stable at that level, and is not significantly affected by learning.

Keywords: Coordination, communication, forward induction, experiment, stag hunt

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I. Introduction

An extensive experimental literature on coordination games explores the role of communication in allowing independent agents to efficiently coordinate their actions (for reviews, see Camerer (2003, Chapter 7) and Devetag & Ortmann (2007)). Particular attention has been devoted to games that involve a tradeoff between Pareto efficiency and greater payoff security (Van Huyck et al., 1990; Cooper et al., 1990). A prominent example is the following stag-hunt game that was studied by Cooper et al. (1992).

Table 1: Stag Hunt Game

		Column Player's Action 1	Column Player's Action 2
Row Player's Action	1	800, 800	800, 0
	2	0, 800	1000, 1000

Cooper et al. (1992) found that without communication the risk-dominant equilibrium (Harsanyi and Selten, 1988), in which both players take action 1, tends to prevail. However, with universal mandatory cheap talk – in which players are required to send a pre-play message of "1" or "2" and the messages are (implicitly) costless – there is a tendency toward the Pareto-efficient equilibrium in which both players take action 2. This finding is consistent with numerous theoretical analyses of the role of cheap-talk pre-play messages in equilibrium selection (Farell, 1988; Kim and Sobel, 1995; Farrell and Rabin, 1996; Blume, 1998; Demichelis and Weibull, 2008) and with experimental evidence from other, related games (Charness, 2000; Blume and Ortmann, 2007). The stylized result from this literature is that inefficiency regularly obtains when players do not communicate, but that efficiency is greatly enhanced through the use of pre-play messages.

In this paper, we revisit pre-play communication in stag-hunt games, both experimentally and theoretically. In particular, we depart from Cooper et al. (1992) by making communication both optional and costly, and principally focus on the case with message costs in the range $c \in (0,200)$. We find that, with such optional costly communication, subjects generally opt not to send messages, but they nevertheless subsequently coordinate their actions efficiently with high frequency. This contrasts with the results obtained by Cooper et al. – which we also replicate in separate treatments with costless and absent communication – that suggest efficient play in the stag-hunt game requires communication.

In another treatment, with message costs, $c > 200$, we show that the beneficial effect of forgone messages for efficient coordination vanishes when message costs become "unreasonable." That is, when message costs become high enough that message use is strictly dominated, players coordinate no better when choosing not to send messages than when messages were unavailable.

Our experimental finding is potentially puzzling from a theoretical perspective. The stag-hunt game with costly messages falls in the class of "money burning" games that were studied in an influential paper by Ben-Porath and Dekel (1992). They showed that as long as only one of the players has the option to send a costly message, playing the efficient action without sending a message is the unique outcome that survives iterated admissibility (IA). They also noted, however, that this no longer true if, as in our experiment, both players have the option to send a message.

Our results can be understood in terms of Govindan and Wilson's (2009) recent definition of forward induction (GW-FI). Applied to our game, GW-FI implements the following reasoning: Take a putative equilibrium in which messages are sent and the efficient action is taken and suppose the row player, Ann, unexpectedly observes that the column player, Bob, did not send a message. If Ann continues to believe that Bob is rational, she will reason that Bob expects at least as high a payoff as he would have received in equilibrium. This requires Bob to take action 2 and hence action 2 is optimal for Ann as well. If, however, Bob believes that Ann reasons in this manner, he strictly prefers to deviate from the putative equilibrium toward not sending a message and taking action 2. This breaks the original equilibrium. Analogous arguments can be used to eliminate all pure-strategy equilibrium outcomes, except the efficient one in which no messages are sent.

The key to understanding the difference in conclusions from applying IA and GW-FI to our game is that GW-FI takes an equilibrium outcome as a starting point. This reference to a putative equilibrium point gives GW-FI extra leverage. Our experimental results suggest that this extra leverage adds explanatory power.

When trying to explain experimental data with appeals to forward induction, we make strong demands on the experimental subjects' ability to reason and therefore it might appear *a* *priori* unlikely that forward induction would play a significant role in explaining initial behavior in experimental games. Indeed, unsurprisingly, not all our observations conform with the FI prediction. Importantly, however, consistent with the introspective character of GW-FI, the fraction of players who achieve efficiency in our games with reasonably costly optional messages is substantial from the first period on. Moreover, it is remarkably stable at that level and not significantly affected by learning. This is unlike behavior in control treatments, where messages are either unavailable or prohibitively costly and where the GW-FI prediction of efficiency does not hold.

The remainder of the paper is organized as follows. Section II presents our theoretical analysis and hypotheses. In Section III we describe our experimental design and in Section IV we report our experimental data. Section V provides a discussion of our findings and relates our results to the literature.

II. Theoretical Analysis and Hypotheses

Our analysis and experiment modify the game in Table 1 in two ways.

First, we introduce an initial stage in which both players simultaneously decide whether to send no message, or to send a message "1" or "2" to the other player. Both players then observe any message sent by the other player, before selecting an action in the second-stage coordination game.

Second, we introduce a cost of sending a message, $c \geq 0$, which is not incurred when a player chooses to send no message. We refer to the special case when $c = 0$ as costless messages. The primary focus of our analysis and experiment deals with situations in which $c \in (0,200)$, meaning that pre-play communication is costly but can be supported as part of an equilibrium strategy. We refer to such a situation as one involving "reasonable" communication costs. We also consider the case where $c > 200$ and therefore sending a message is possible but dominated – i.e., "unreasonable" message costs. Whether message costs are above or below 200 significantly affects both our theoretical analysis and the experimental results. We begin by considering the case of reasonable message costs ($c \in (0,200)$), which is the focus of our study, and return later to the cases with costless communication ($c = 0$) and unreasonable message costs ($c > 200$).

In our analysis, without loss of generality we will lump together strategies of a player that differ only at information sets ruled out by that player's strategy; e.g. if a player's strategy specifies sending a message, we will not explicitly keep track of that player's continuation play in the event that he does not send a messages. All the strategies that we group together are outcome equivalent and indistinguishable by opponents and outside observers. The only effect of carrying the distinction along would be to increase notational burden. In our game with two costly messages, the option of not sending a message, and two choices at the action stage, each player has 3×2^9 strategies before and 24 strategies after grouping together outcome-equivalent strategies.

Before applying Govindan and Wilson's forward induction (GW-FI) test to our game, we briefly recall the limited power of Iterative Admissibility (IA), Extensive Form Rationalizability (EFR), and Fully Permissible Sets (FPS) when two players have the option to burn money. To keep this part of the analysis tractable we conduct it for the one-message game where each player has exactly one costly message; later, when we return to applying GW-FI, we do so for the two-message game where each player has two costly messages as in our experiment. In the one-message game, a player who uses strategy *Mij* sends a message, takes action *i* if he receives a message and takes action *j* if he does not receive a message. Similarly *Nij* stands for the strategy of not sending a message, responding to a message with action *i* and taking action *j* if no message is received. For convenience, Table 2 reports the payoffs from all resulting combinations of these strategies.

Table 2: Communication Game with One Costly Message

	M22	M21	M12	M11	N22	N21	N12	N11
M22	1000-c, 1000-c	1000-c, 1000-c	-c, 800-c	-c, 800-c	1000-c, 1000	1000-c, 1000	-c, 800	-c, 800
M21	1000-c, 1000-c	1000-c, 1000-c	-c, 800-c	-c, 800-c	800-c, 0	800-c, 0	800-c, 800	800-c, 800
M12	800-c, -c	800-c, -c	800-c, 800-c	800-c, 800-c	1000-c, 1000	1000-c, 1000	-c, 800	-c, 800
M11	800-c, -c	800-c, -c	800-c, 800-c	800-c, 800-c	800-c, 0	800-c, 0	800-c, 800	800-c, 800
N22	1000, 1000-c	0, 800-c	1000, 1000-c	0, 800-c	1000, 1000	0, 800	1000, 1000	0, 800
N21	1000, 1000-c	0, 800-c	1000, 1000-c	0, 800-c	800, 0	800, 800	800, 0	800, 800
N12	800, -c	800, 800-c	800, -c	800, 800-c	1000, 1000	0, 800	1000, 1000	0, 800
N11	800, -c	800, 800-c	800, -c	800, 800-c	800, 0	800, 800	800, 0	800, 800

Informally, players in a game use forward induction when they seek to predict another player's future behavior by rationalizing his past actions. There are two strands in the literature that formalize this idea, one that references putative equilibrium outcomes and one that does not. The non-equilibrium literature on forward induction starts with Pearce's (1984) introduction of the extensive-form rationalizability condition (EFR). The key idea is that a player will not use a strategy that fails to be a best response to all beliefs at an information set reached by that strategy. Strategies that do not pass this test are eliminated and the test is repeated on the reduced set of strategies until the process converges (to the EFR set).

EFR has forward induction implications because, at a given information set, it restricts the beliefs of the player moving there about strategies of others in accordance with their rationality.[1] The conditions on players' rationality and beliefs that give rise to EFR and related notions of iterated dominance have been clarified by the epistemic game theory literature. In particular, Battigalli and Siniscalchi (2002) show that EFR corresponds to *rationality and common strong belief in rationality* on complete type spaces. A similar characterization is available for iterative admissibility (IA), where in each round all weakly dominated strategies of all players are deleted; m+1 rounds of iterative deletion of weakly dominated strategies corresponds to *rationality and m-th order assumption of rationality* with complete type structures (Brandenburger, Friedenberg and Keisler, 2008). Finally, Asheim & Dufwenberg (2003) propose their notion of fully permissible sets (FPS), which in general neither implies nor is implied by IA or EFR, despite underlying assumptions that rule out weakly dominated strategies.

EFR, IA, and FPS come to the same conclusion for the one-message game. All three rule out the strictly dominated strategy M11 of sending a costly signal and then unconditionally playing action 1, and no more. Ben-Porath and Dekel (1992) already noted this coarseness of the IA prediction in money-burning games where more than one player has the option to burn money. For the sake of completeness we include proofs of all three claims for our game.

[1] A classical example of the power of this idea is its application to the battle of the sexes with an outside option: Player 1 has the choice between an outside option with a common payoff of 2 and entering a "battle of the sexes" with payoff pairs (3,1) and (1,3) at the two pure-strategy equilibria and (0,0) otherwise. Player 1's strategy of opting in and then playing for (1,3) is strictly dominated. Hence, if Player 2 is called upon to move he must believe Player 1 aims for (3,1). Given those restricted beliefs the strategy that might have given Player 2 a payoff of 3 is no longer a best reply and it is uniquely optimal for him to play according to the (3,1) equilibrium in the continuation game. As a result, Player 1 opts in and the forward-induction equilibrium payoff pair is (3,1).

Claim. *In the game where both players have a single costly message, with the exception of the strategy of sending a message and then taking action 1 unconditionally (M11), all pure strategies belong to the set of iteratively admissible (IA) strategies.*

Proof: We will check one by one that none of the remaining pure strategies are (weakly) dominated by either a pure or a mixed strategy, both before and after the strictly dominated strategy M11 is eliminated. Since the arguments for both cases are exactly the same, we will not explicitly distinguish them.

For N11 to be dominated, it has to be dominated by N21, the only other best reply against N11. But N21 does strictly worse against M21.

For N12 to be dominated, it has to be dominated by N22, the only other best reply against N22. But N22 does strictly worse against M21.

For N21 to be dominated, it has to be dominated by N22, the only other best reply against M12. But N22 does strictly worse against N21.

For N22 to be dominated, it has to be dominated by N21, the only other best reply against M22. But N21 does strictly worse against N22.

For M12 to be dominated, it has to be dominated by M22, the only other best reply against N21. But M22 does strictly worse against M12.

For M21 to be dominated, it has to be dominated by M22, the only other best reply against M21. But M22 does strictly worse against N12.

For M22 to be dominated, it has to be dominated by M21, the only other best reply against M21. But M21 does strictly worse against N22. **QED**

Claim. *In the game where both players have a single costly message, with the exception of the strategy of sending a message and then taking action 1 unconditionally (M11), all pure strategies belong to the set of extensive-form rationalizable (EFR) strategies.*

Proof: It suffices to construct for each pure strategy *S* that remains after M11 is removed and for every information set that is not ruled out by *S* a conjecture whose support does not include M11 and for which the strategy *S* is a best reply at that information set. Note that at an information set that is reached given the initial conjecture, the conjecture has to remain unchanged. We will use only conjectures that assign probability one to a pure strategy. It then suffices for every strategy *S* to specify an initial conjecture C_S and a conjecture for the information set that is reached when C_S is proved wrong. Denote this alternative conjecture by C_A; if, for example, a player initially conjectures that the other will send a message, he will need an alternative conjecture for the event that he does not receive a message. Accordingly we will list for each strategy S a triple (S; C_S, C_A). One checks immediately that in the following list of such triples the strategy S is a best reply at the appropriate information sets: (M22; M21, N21), (M21; M21, N12),(M12; N21, M12), (N22; N22, M22), (N21; M12, N11), (N12; N12, M21), (N11; N11, M21). **QED**

Claim. *In the game where both players have a single costly message, with the exception of the strategy of sending a message and then taking action 1 unconditionally (M11), all pure strategies belong to a fully permissible set.*

Proof: We will not reproduce Asheim & Dufwenberg's (2003) definitions here. Suffice it to note that (as easily inferred via their paper) if we can find for each player a non-empty subset of strategies such that no contained strategy is weakly dominated given that the opponents are restricted to choose from their subsets, then each player's subset is fully permissible. Applied to Table 2, we infer that for either player {M22, M21, M12, N22, N21, N12, N11} is fully permissible (as seen if we pick that subset for each player). The veracity of the claim is implied. **QED**

Note that, in particular, EFR (IA, FPS) does not rule out the outcome where no messages are sent and both take action 1. This is because sending a costly message and then playing action 1 is rational if it was done in the hope that the other player would also send a message but that message is not forthcoming. Therefore a player who observes the other player sending a message may nevertheless rationally believe that that player will take action 1. When both players have the option of sending a message, messages can be viewed as conditional statements. Sending a message may then be an offer of conditional cooperation: "I will take action 2 provided you send a message as well." In contrast, as we will see, with an approach that emphasizes the role of a putative equilibrium outcome, a player who sends an off-equilibrium-path message has no expectation of the other player sending a message as well. Since the other player's actions are pinned down by the equilibrium, his messages are unconditional and can be interpreted using equilibrium dominance: The deviating player expects at least as much from his deviation as from the reference equilibrium.

This equilibrium refinement approach to forward induction dates back to Kohlberg and Mertens (KM) (1986). They coined the term and in their Proposition 6 associated it with the property of stable sets of equilibria containing stable sets of games obtained by removing strategies that are not best replies to any of the equilibria in the set. KM did not formally define forward induction. For this reason and for its ease of applicability we use Govindan and Wilson's (2009) closely related definition (hereafter referred to as GW-FI).

We apply GW-FI to the two-message game that we used in our experiment. Recall that we do not distinguish a player's strategies that differ only in behavior at information sets that are precluded by those strategies. Then, a strategy μijk with $\mu \in \{M_1, M_2, N\}$ and $i, j, k \in \{1,2\}$ specifies the choice of message (or none) μ, the response i to message M_1, the response j to message M_2 and the response k to no message, N. The key to both the KM notion and the GW definition of FI is an equilibrium dominance argument: Players should assign probability zero to strategies of their opponents that result in a lower payoff than from the equilibrium in question. We will find that among all pure-strategy equilibrium outcomes only one survives Govindan and Wilson's forward induction condition. Specifically, GW-FI rejects the equilibrium outcome $\boldsymbol{NN}$-**1** in which neither player sends a message and both take action 1, the equilibrium outcomes $\boldsymbol{M_r M_s}$-**2** with $r, s = 1{,}2$ in which players send message $\boldsymbol{M_r}$ and $\boldsymbol{M_s}$, respectively, and take action 2 and the equilibrium outcomes $\boldsymbol{NM_s}$-**2** and $\boldsymbol{M_s N}$-**2**, s=1,2, in which exactly one player sends a message and then both players take action 2. GW-FI does not reject the equilibrium outcome $\boldsymbol{NN}$-**2** in which players send no message and take action 2.

The GW-FI conclusions can be understood informally via the following "forward-induction reasoning": For the sake of concreteness let the game be played between Ann and Bob. Consider the putative equilibrium outcome $\boldsymbol{NN}$-**1** and suppose that Ann (unexpectedly) observes a message M_2 from Bob. If she maintains her belief in Bob's rationality, she must reason that Bob expects at least the payoff from the putative equilibrium **NN-1.** This, however, is impossible with costly messages unless Bob plans to take action 2. Thus, following Bob's message 2, Ann must believe that Bob will take action 2. Given those beliefs, Bob strictly prefers to deviate from $\boldsymbol{NN}$-**1.** Similarly, consider the putative equilibrium outcome $\boldsymbol{M_r M_s}$-**2** and suppose that Ann (unexpectedly) observes no message from Bob. If this move by Bob is rational, then Bob must expect to get a payoff from this move that is at least as high as his payoff under the equilibrium outcome $\boldsymbol{M_r M_s}$**-2.** This, however, requires that Bob take action 2 in the continuation game. Given this belief on Ann's part, Bob strictly prefers to deviate from $\boldsymbol{M_r M_s}$**-2.** The argument for the equilibrium outcomes $\boldsymbol{NM_s}$**-2** and $\boldsymbol{M_s N}$**-2**, s=1,2, is essentially the same as for $\boldsymbol{M_r M_s}$**-2.** Finally, the equilibrium outcome $\boldsymbol{NN}$**-2** survives the GW-FI test since every deviation that changes this equilibrium outcome strictly lowers the deviating player's payoff. Thus among the pure-strategy equilibrium outcomes, only the one where players forgo messages and play efficiently survives.

Govindan and Wilson (2009) define forward induction in terms of Reny's (1992) "weak sequential equilibrium." Weak sequential equilibrium coincides with Kreps and Wilson's (1982) sequential equilibrium, except that a player's strategy need not prescribe best replies at information sets that are ruled out by that strategy. GW use a variant of weak sequential equilibrium in which beliefs at an information set are distributions over other players' strategies rather than over nodes in that information set.

Recall that an equilibrium outcome in a game is the distribution over terminal nodes induced by the strategies that support that equilibrium. The key concept in GW's definition of FI is that of a ***relevant strategy***: A pure strategy is relevant for the outcome of a game if there exists a weakly sequential equilibrium with that outcome such that the strategy is a best reply to equilibrium beliefs at every information set not excluded by that strategy. An information set is relevant for an outcome provided that not every combination of strategies relevant for that outcome precludes it. The forward induction requirement then asks that at relevant information sets beliefs be concentrated on relevant strategies.

Definition. (Govindan and Wilson, 2009) *An outcome satisfies* ***forward induction*** *if it results from a weakly sequential equilibrium in which at every information set that is relevant for that outcome the support of the belief of the player acting there is confined to profiles of Nature's strategies and other players' strategies that are relevant for that outcome.*

The following result classifies all pure-strategy equilibrium outcomes in the two-message game according whether or not they satisfy forward induction.

Claim. *In the game where each player has the option to either send no message,* $\boldsymbol{N}$*, or one of two costly messages,* $\boldsymbol{M_1}$ *and* $\boldsymbol{M_2}$*, (1) the equilibrium outcome* $\boldsymbol{NN}$**-1** *in which players send no message and take action 1 fails to satisfy forward induction; (2) the equilibrium outcomes* $\boldsymbol{M_r M_s}$***-2*** *with* $r, s = 1{,}2$ *in which players send message* $\boldsymbol{M_r}$ *and* $\boldsymbol{M_s}$ *respectively and take action 2 fail to satisfy forward induction; (3) the equilibrium outcomes* $\boldsymbol{NM_s}$**-2** and $\boldsymbol{M_s N}$**-2**, s=1,2, *in which exactly one player sends a message and both take action 2 fail to satisfy forward induction; and, (4) the equilibrium outcome* $\boldsymbol{NN}$**-2** *in which players send no message and take action 2 satisfies forward induction.*

Proof: (1) The $\boldsymbol{NN}$**-1** outcome is supported by the set of mixtures of strategies *Nij1, i,j=1,2,* that assign probabilities p_{Nij1} to those strategies that satisfy

$$p_{N211} + p_{N221} \leq \frac{800 + c}{1000}\text{, and} \qquad (1)$$

$$p_{N121} + p_{N221} \leq \frac{800 + c}{1000}\,. \qquad (2)$$

The set of strategies that is relevant for this outcome is $\{Nij1, M_1ij2, M_2ij2\}_{i,j=1,2}$. Hence, at the (relevant) information set of player 1 where player 1 unexpectedly observes player 2 having sent message M_2, GW-FI requires us to restrict player 1's beliefs over player 2's strategies to the set $\{M_2ij2\}_{i,j=1,2}$. Against such beliefs neither *N111* nor *N211* are best replies. Therefore all best replies of player 1 that satisfy the GW-FI belief restriction violate condition (2).

(2) The $\boldsymbol{M_1M_2}$***-2*** outcome (which we examine representatively for all $\boldsymbol{M_rM_s}$***-2*** equilibrium outcomes) is supported by mixtures over player 1's strategies M_1i2k, with $i, k = 1{,}2$ that satisfy

$$p_{M_1 122} + p_{M_1 222} \leq \frac{1000 - c}{1000} \qquad (3)$$

and by mixtures over player 2's strategies $M_2 2jk$, with $j, k = 1{,}2$ that satisfy

$$p_{M_2 212} + p_{M_2 222} \leq \frac{1000 - c}{1000}\,. \qquad (4)$$

The set of player 2's strategies that is relevant for this outcome is $\{N2jk, M_1 2jk, M_2 2jk\}_{j,k=1,2}$. Hence, at the (relevant) information set of player 1 where player 1 unexpectedly observes player 2 not having sent a message, GW-FI requires us to restrict player 1's beliefs over player 2's strategies to the set $\{N2jk\}_{j,k=1,2}$. Any mixture over player 1's strategies $M_1 i2k,$ with $i,k=1,2,$ that is a best reply to such beliefs must satisfy $p_{M_1 121}=p_{M_1 221}=0$ and therefore $p_{M_1 122}+p_{M_1 222}=1,$ in violation of condition (3).

(3) The $\boldsymbol{NM_2}$**-2** outcome (which we examine representatively for all $\boldsymbol{NM_s}$***-2*** and $\boldsymbol{M_s N}$***-2*** equilibrium outcomes, s=1,2) is supported by arbitrary mixtures of player 2 over strategies in the set $\{M_2 ij2\}_{i,j=1,2}$ and by mixtures of player 1 over strategies in the set $\{Ni2k\}_{i,k=1,2}$ that satisfy the condition

$$p_{N122}+p_{N222}\leq\frac{1000-c}{1000}\ . \qquad (5)$$

The set of strategies of player 2 that is relevant for this outcome is $\{Nij2, M_1 ij2, M_2 ij2\}_{i,j=1,2}$. Consider the relevant information set of player 1 who has followed his equilibrium strategy, not sent a message and who has observed a deviation by player 2 to not sending a message. GW-FI requires us to restrict the support of player 1's beliefs at this information set to the set of strategies $\{Nij2\}_{i,j=1,2}$. Against such beliefs, however, no strategy of player 1 that assigns positive probability to any of the strategies in the set $\{Ni21\}_{i,j=1,2}$ is a best reply. Any mixture over player 1's strategies $Ni2k,$ with $i,k=1,2,$ that is a best reply to such beliefs must satisfy $p_{N121}=p_{N221}=0$ and therefore $p_{N122}+p_{N222}=1,$ in violation of condition (5).

(4) The equilibrium outcome ***NN*-2** is supported by arbitrary mixtures over strategies in the set $\{Nij2\}_{i,j=1,2}$. These strategies are also the relevant strategies. Hence the only relevant information sets for this outcome are the ones where neither player has sent a message. Since they are on the equilibrium path, the belief restriction has no bite. **QED**

Based on these theoretical considerations, ***we predict that in our experiment, with the option to send reasonably costly messages*** ($c\in(0,200)$), ***the modal behavior will be for players not to send messages and to take action 2*** *(Hypothesis 1).* Given that Cooper et al. (1992) and others found coordination difficult to achieve without pre-play messages, this theoretical hypothesis is of special interest. Note that it is of further interest, as it is the unique equilibrium outcome selected by one class of approaches to forward induction.

Further support for this prediction comes from the fact that, as shown by Hurkens (1996), it is the *unique* outcome that is supported by equilibria belonging to a minimal *curb* (closed under rational behavior) set (Basu and Weibull, 1991). Curb sets are sets of strategies that are closed under inclusion of best replies and minimal curb sets do not strictly contain another such set. In the case of a unique minimal curb set, as in our game, a player who reasons through the game in terms of iterating best replies will eventually find himself caught in the unique minimal curb set, regardless of his starting point. Each curb set contains a persistent retract (Kalai and Samet, 1984) and each persistent retract contains a strategically stable set of equilibria, which then satisfies the forward property articulated in Proposition 6 of Kohlberg and Mertens (1986).[2]

Our prime motivation for introducing curb sets is, however, that they help us offer a unified treatment of the burning-money ($c \in (0,200)$) and cheap-talk variants ($c = 0$) of our game. Blume (1998) shows that, with multi-sided pre-play communication, if the underlying game has a unique efficient action profile, then under a mild behavioral assumption (that agreement on an equilibrium action profile confers an infinitesimal payoff boost to that profile) every strategy profile in the unique minimal curb retract is an efficient equilibrium in which each player sends message 2. Based on this, ***we predict that in our experiment, with the option to send costless messages*** (c = 0), ***the modal behavior will be for players to send message "2" and to take action 2*** *(Hypothesis 2).* That is, we expect to replicate the findings of Cooper et al. (1992) in this environment. At the same time, under the same behavioral assumption we also recover our prediction for the burning-money game of efficient play *without* messages (Hypothesis 1).

We next consider the case with unreasonably costly messages ($c > 200$). Here, the above forward induction intuition and analysis fail to select the efficient outcome because 1000-c < 800, which means that sending a message, regardless of the outcome in the second-stage subgame, is strictly dominated by not sending a message and selecting action 1. Thus, to return to our earlier example, the absence of a message from Bob tells Ann nothing about what Bob intends to do, as he would never send a message. The elimination of all strategies that employ messages reduces the game to the game in Table 1. Prior research, e.g., Cooper et al. (1992), indicates that behavior in this game will converge to the inefficient (1,1) equilibrium. Therefore,

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[2] Our game has mixed strategy equilibrium outcomes in which all message options, sending no message, sending message 1 and sending message 2, have strictly positive probability. For example, there is an equilibrium in which both players mix over their strategies $N111, M_1221, M_2221$ with probabilities $\frac{200-c}{200}, \frac{c}{400}$ and $\frac{c}{400}$ respectively. While these outcomes pass the Govindan-Wilson test, persistence and the minimal curb condition suggest that these outcomes are fragile.

we predict that in our experiment, with unreasonably costly messages ($c > 200$)), ***the modal behavior will be for players not to send messages and to take action 1*** *(Hypothesis 3)*.

We make the same prediction for the treatment in which messages are not possible, and message costs are therefore implicitly infinite. That is, ***we predict that in our experiment, with no messages***, ***the modal behavior will be for players to take action 1*** *(Hypothesis 4)*. As with Hypothesis 2, this essentially predicts a replication of Cooper et al. (1992).

With these hypotheses in mind, we proceed to our experimental test.

III. Experimental Design

The experiment is modeled after Cooper et al. (1992), in which subjects played the game in Table 1 either with or without communication.[3] The experiment was conducted at the University of Pittsburgh's Experimental Economics Laboratory (PEEL). Each session in our study consisted of ten different subjects, recruited by email from Carnegie Mellon University, the University of Pittsburgh and the surrounding community.

At the beginning of a session, players sat at separate computers and read instructions on the screen as they were read aloud by the experimenter.[4] Before playing the game, every participant completed a quiz to verify understanding of payoffs, communication rules, and the matching procedure. The experimenter answered questions privately.

Experimental Conditions

The five conditions are summarized in Table 3, which also presents the relevant cost parameter, *c*, for each condition. We also include our theoretical predictions.

We conducted a no communication baseline (*No Messages*) in which subjects played the game repeatedly with re-matching after every period. In this treatment, participants played the one-shot stag hunt game in Table 1 for forty periods. The payoffs in Table 1 corresponded to

[3] Other than the treatment differences, our design choices generally follow those of Cooper et al., with the exception that we simplified the procedure where possible and also modified the design to collect more data. For example, instead of using 11 subjects with one excluded each period, we used 10 subjects. Instead of 11 practice rounds of a dominant strategy game followed by 22 real rounds, we included no practice rounds and 40 real rounds. Instead of each subject being matched with every other subject exactly twice (in random order), we used random matching. And finally, instead of a payoff procedure that involved a lottery, we converted all earnings in ECU directly into U.S. dollars (with an exchange rate that kept the numerical payoffs in the stage game consistent with Cooper et al.).
[4] The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007). Instructions for one treatment (with $c = 10$) are provided in the Appendix.

"Experimental Currency Units" (ECU), and were converted to dollars at the end of the experiment at the known exchange rate of $1 per 2500 ECU. Each period, participants were anonymously and randomly re-matched, played the one-shot game, and saw the results of that period. In every period after the first, players saw the history of their own prior plays of the game (own choice, opponent's choice and resulting outcome), but did not know the identity or history of their current opponent.

Our four conditions with messages depart from Cooper et al.'s design in two main ways, consistent with our analysis in Section II.

First, we allowed subjects to choose whether to send a message. Therefore, in a *Costless Messages* condition subjects chose at the beginning of each period whether to send a costless message to their opponent. Payoffs were not directly affected by this choice. Subjects selected either N ("no message"), M_1 ("1"), or M_2 ("2"), by clicking on one of the three options on a screen. After every subject made this choice, and corresponding opponents were informed of the message choice, subjects proceeded to play the game in Table 1. While this treatment differs slightly from Cooper et al.'s two-way communication treatment, in which messages were costless but subjects were required to send messages, we expect the two treatments to be quite similar in that there is little reason for subjects in our Costless Messages condition not to send messages. This prediction is also consistent with our Hypothesis 2.

Our second modification is more important. We include three conditions in which messages are costly, meaning that a player's payoff from Table 1 was decreased by a cost, c, if that player chose to send a message to her opponent. There was no cost if a player chose not to send a message, and subjects always observed, at no cost, any message from the opponent. Subjects made their choices in exactly the same manner as in the Costless Messages condition, except that now the cost of sending a message, in ECU, was presented next to the possible message choices "1" and "2", while the "no message" option explicitly indicated no cost.

Our three costly communication conditions varied the cost associated with sending a message. In two conditions with *Reasonably Costly* messages ($\boldsymbol{c} \in (\mathbf{0}, \mathbf{200})$), RC-10 and RC-100, sending a message cost 10 and 100 ECU, respectively. In a condition with Unreasonably Costly messages ($c > 200$), UC-300, sending a message cost 300 ECU. Our analysis predicts different behavior for the two kinds of message costs, as presented in Table 3.

IV. Results

We conducted three sessions each of the Costless Messages and No Messages conditions, seven sessions each of the two conditions with Reasonably Costly messages, RC-10 and RC-100, and five sessions of the condition with Unreasonably Costly messages (UC-300), using a total of 250 subjects. In our analysis, we explore several different characteristics of the results, including the sending of messages, aggregate action choices and outcomes, individual behavior, and earnings.

A. Message Use

The first question we ask is how message costs affected the frequency of message use. Recall that our analysis predicted that message "2" would be very frequent with Costless Messages but less frequent in the three conditions with Costly Messages (see Table 3).

We find that message costs strongly affect message use. Under Costless Messages, message "2" was sent 89.3 percent of the time. However, with message costs, far fewer messages were sent: the frequency of message "2" was 24.4 percent for $c = 10$, 11.3 percent for $c = 100$, and 4.8 percent for $c = 300$.[5] Thus, the data generally support our predictions concerning message use – message "2" is used very frequently with Costless Messages, but rarely in all conditions with Costly Messages.

Table 4 reports probit regressions, with subject random effects, using the choice to send message "2" as the dependent variable. The regressions use only data from the four treatments in which messages were possible. As model 1 reveals, the frequency of message use is significantly lower in all Costly Message conditions, relative to the condition with Costless Messages.[6] Thus, message costs – even very small ones as in RC-10 – significantly decrease message use.[7]

To explore possible heterogeneity in message use across subjects, Figure 1 shows the distributions of message frequency by subject in each of the four conditions with

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[5] As expected, message "1" was sent very rarely (never more than 1.2 percent of the time in any condition). In a large majority of these cases (86 percent), subjects followed a message of "1" by playing action 1, and no subject sent message "1" and subsequently chose action 2 more than one time in the forty periods.

[6] In a more conservative statistical test, we calculate the frequency of message "2" use in a session and use this session-level statistic as the unit of observation in a non-parametric Wilcoxon rank-sum test of differences across conditions. The difference in frequency of message "2" use between the Costless Message condition and either RC-10, RC-100, or UC-300 is statistically significant (respectively, $z = 2.39$, $p < 0.02$; $z = 2.39$, $p < 0.02$; and $z = 2.24$, $p < 0.03$). Among the conditions with Costly Messages, only the difference between RC-10 and UC-300 is statistically significant ($z = 2.36$, $p < 0.02$).

[7] The coefficients for the three Costly Message conditions in model 1 differ significantly and are ordered such that fewer messages are used as costs increase. While our predictions do not account for any differences between the three treatments with costly messages, it is not entirely surprising to find fewer messages with higher costs.

communication. Each graph shows, for a particular condition, how often a subject sent message "2", represented on the horizontal axis, ranging from never (0) to doing so in every period (1). The vertical axis presents the frequency of each particular message use profile among subjects in that condition. When messages were Costless, a large majority of subjects sent message "2" in every period.[8] However, in the three Costly message conditions, the modal behavior was to send no messages at any point in the experiment.

While we find, as predicted, that subjects used messages far less frequently in the Costly Message conditions, there exists a possibility that this difference surfaced over the course of the experiment, and that subjects in all conditions initially sent messages with high frequency, but stopped doing so in the Costly conditions. The data reject this interpretation. As model 2 in Table 4 reveals, there is no significant trend in message "2" use across periods in any condition, while model 3 reveals that message use was significantly lower under costly messages when considering only the first period. Additionally, the frequency of message "2" is never much higher in any period of the Costly message conditions than the corresponding aggregate frequencies above – the highest frequencies of message "2" use in any period are 34.2 percent in RC-10, 17.1 percent in RC-100, and 12 percent in UC-300 – and this frequency is never lower than 83.3 percent in any period of the Costless Messages condition.

The message use by subjects in the experiment therefore strongly confirms the first part of our predictions in Table 3. Whether on aggregate, by individual subject, or across periods, costless messages are used with very high frequency, while costly messages are used rarely.

B. Actions in the Stag Hung Game

We now consider the second part of the predictions in Table 3, that the modal behavior in the post-message subgame should be action 2 when messages are Costless or Reasonably Costly (RC-10 and RC-100) and action 1 when messages are either Unreasonably Costly (UC-300) or there are No Messages. Figure 2 presents the frequency of action 2 choices across periods, separately for each treatment.

Under No Messages and Costless Messages, we expected to replicate the findings in

[8] Three subjects in Costless Messages rarely or never sent message "2" even though doing so was costless. One of these subjects had poor vision and experienced difficulty reading the screen and clicking on the radio buttons. The other two repeatedly played action 1, and sent the corresponding message, perhaps out of altruism (i.e., to ensure that their opponent did not receive the zero payoff).

Cooper et al. (1992), who found efficient coordination rare when pre-play communication was not possible but frequent under costless communication. This is also generally the case in our data. Action 2 was chosen only 42 percent of the time with No Messages, and only 30 percent of the time in the final ten periods.[9] With Costless Messages, we predicted that a high frequency of message "2" would support a high frequency of action 2 choices. Having already observed a high frequency of "2" messages, the 87 percent of choices of action 2 further corroborates our prediction. Therefore, action choices generally support Hypotheses 2 and 4.

We next consider Reasonably Costly messages ($c \in (0,200)$). Despite the low frequency of message use in these conditions, we observe high frequencies of action 2 in both RC-10 (83 percent) and RC-100 (76 percent), and these are similar to the frequency observed with Costless Messages (87 percent). In fact, by the final 10 periods action 2 was selected between 80 and 83 percent of the time in *all three* of the conditions where we predicted a high frequency of that action, despite the very different frequencies of messages. Thus, combining the frequency of messages and action 2 choices in the treatments with Reasonably Costly messages, we find strong support for our main prediction (Hypothesis 1). The availability of optional, and reasonably costly, pre-play messages seems sufficient to obtain a high frequency of efficient coordination – subjects do not actually have to use the messages.

Finally, we consider the condition with Unreasonably Costly messages, UC-300, where we predicted the modal choice in the stag hunt game would be action 1 (Hypothesis 3). The data also confirm this prediction: action 2 is selected 28 percent of the time in this treatment, and this frequency converges downward over the course of the experiment. Thus, while message use was infrequent in all conditions with Costly messages, forgone messages only facilitated efficient coordination in the two conditions with Reasonably Costly messages, as we predicted.

Table 5 reports random-effects probit regressions that use as the dependent variable whether a subject chose action 2 in a period. The first model confirms our predictions regarding behavior across treatments: action 2 is chosen significantly more frequently with Costless or Reasonably Costly Messages, than with either No Messages (the omitted category) or

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[9] There is some heterogeneity across sessions, particularly in the No Messages condition (see Figure 5). In two sessions, convergence to action 1 occurred as predicted, while in the remaining No Message session behavior converged to action 2. Therefore, coordination on the inefficient game equilibrium (1,1) is weaker than that observed by Cooper et al. (1992), though we find it to be the case in two of three sessions. Note that this discrepancy with Cooper et al.'s results works against finding support for our hypotheses. Some procedural differences between the two experiments may explain the disparity (see footnote 3).

Unreasonably Costly Messages. We fail to reject the restriction that the three coefficients for Costless Messages, RC-10, and RC-100 are equal ($\chi^2(2) = 4.32$, $p = 0.12$).

Model 2 includes time trends for each condition, and confirms some patterns from Figure 2. For example, the frequency of action 2 decreases across periods both with No Messages and Unreasonably Costly Messages, and the decrease is larger with the latter. More importantly, in model 2 the intercepts and time trends differ for the three remaining conditions (Costless, RC-10 and RC-100). While the difference between the coefficients for these three intercepts is statistically significant ($\chi^2(2) < 15.50$, $p < 0.001$), the differences in the frequencies of first-period action 2 choice across these three conditions are small (Costless: 90 percent; RC-10: 79 percent; RC-100: 80 percent) and none of the pairwise first-period comparisons at the subject level are statistically significant ($\chi^2(1) < 1.83$, $p > 0.17$, in all comparisons). To further explore differences in first period behavior, model 4 in Table 5 reports the same regression as model 1, but using only first period data. The coefficients for the three conditions in which we predicted a high frequency of action 2 choices – Costless Messages and the two conditions with Reasonably Costly messages – are positive and significant, jointly significantly different from zero ($\chi^2(3) = 11.64$, $p < 0.01$), and do not differ statistically from each other ($\chi^2(2) = 1.98$, $p = 0.37$).

To summarize, our analysis so far strongly confirms all of our hypotheses. Confirming prior research, subjects who cannot send messages tend to select action 1 (Hypothesis 4), while costless messages facilitate action 2 (Hypothesis 2). However, messages appear unnecessary when they are Reasonably Costly ($c \in (0,200)$), as subjects in these conditions do not send messages, yet they select action 2 with frequencies very similar to those under Costless messages. This supports our main prediction (Hypothesis 1), based on the definition of forward induction in Govindan and Wilson (2009). Our claim that higher action 2 frequencies with forgone costly messages are due to the kind of reasoning underlying forward induction is further supported by the fact that, as message costs become unreasonable ($c > 200$), subjects send few messages but modal behavior changes dramatically toward action 1. Thus, the inference subjects' draw from the reasonableness of a forgone message seems critical. All of this is supported both when considering data from all 40 periods or only the first period.

C. Individual Actions Conditional on Messages

Our prior analysis confirms our hypotheses when looking, separately, at message and choice behavior. To provide a stronger test, we also consider these two aspects of a player's strategy jointly. At the root of our main prediction (Hypothesis 1) is that subjects in the conditions with Reasonably Costly messages select action 2 with high frequency when they do not receive a message from their opponent, but that subjects in the Unreasonably Costly and No Message conditions select action 1 in the absence of messages.

Figure 3 shows the frequency of action choices 2 (dark shading) and 1 (light shading) conditional on a message of "2" being sent or received in each condition.[10] The label above each panel presents the message profile, (message sent, message received), indicating both the message sent by the subject and the message received from the opponent. The percentages over each bar indicate the frequency in that particular condition for that particular message profile. For example, the bottom right panel, labeled (2,2), presents instances in which both the focal player and her opponent sent message "2", which occurred with a frequency of 80 percent under Costless Messages, 8 percent in RC-10, 2 percent in RC-100, and never occurred in UC-300 or, of course, under No Messages. In this panel, it is apparent that when a player both sent a message and also received a message from the opponent, the player chose 2, regardless of message cost (at least for $c < 200$).

Turning to the diagonal panels, in which a subject either sent no message but received one (none, 2) or sent a message but did not receive one (2, none), we find interesting differences between the communication treatments. In particular, with Costless Messages, such communication outcomes resulted in fewer than half of subjects playing action 2 subsequently.[11] However, in the conditions with Reasonably Costly messages (RC-10 and RC-100) the proportion of action 2 choices is much higher in both panels, and is close to one.

Most importantly for our purposes, consider the top-left panel, when no messages are sent. Under the complete absence of messages, subjects are more likely to choose action 2 when sending a message would have been Reasonably Costly (RC-10: 75.5%; RC-100: 71.8%) than when sending a message was Unreasonably Costly (22.5%) or simply not possible (42.4%).[12]

[10] In the few instances in which subjects sent a message of "1" they and their opponents usually subsequently chose action 1. This is consistent with subjects who decide to play action 1 in the game and exhibit other-regarding preferences toward their opponent.

[11] Note that the Costless Messages data in the (none, 2) panel is almost entirely composed of the three subjects with irregular message behavior (see footnote 8). The Costless Messages data in the (2, none) panel is composed almost entirely of *responses* to these subjects by their opponents.

[12] The frequency of action choice 2 under Costless Messages in the top-left (none, none) panel is not highly informative as this message profile occurred very infrequently.

Thus, as we hypothesized, the absence of messages results in different action responses based on whether sending a message would have been reasonable or possible.

To provide statistical evidence that the absence of messages is interpreted differently under Reasonably Costly messages than in other conditions, model 3 in Table 5 explores how behavior changes across conditions in response to receiving a message of “2” from an opponent. Since a subject’s own message is endogenous, we do not include own message as an explanatory variable. When including whether a message was received, the coefficient for the Costless Message condition becomes statistically insignificant, while the coefficient for Received Message “2,” which applies to this condition, becomes positive and statistically significant. This shows that simply being in the Costless Message condition does not increase the likelihood of an action 2 choice – when messages are costless it is also necessary that one’s opponent send a message of “2.” However, the coefficients for the two conditions with Reasonably Costly messages are positive and statistically significant, indicating that receiving messages is unnecessary in these conditions to see an increase in action 2 choice. That is, action 2 choices increase significantly from simply being in these conditions, regardless of whether a message of “2” is received. This is consistent with our primary hypothesis (H1), that the possibility of reasonably costly messages is sufficient to facilitate play consistent with the efficient equilibrium.[13]

Of course, the above analysis pools behavior across all periods and therefore may reflect cohort effects and path dependencies. Therefore, to conduct a conservative statistical test of this finding, in model 5 we examine behavior in the first period alone, looking at the frequency of action 2 choices *only* in cases where no messages were used by either player.[14] The model confirms the above analysis – the absence of any messages yields at least marginally significantly more action 2 choices in both conditions with Reasonably Costly messages, relative to when messages are not possible, but no significant increase when messages are Unreasonably Costly. Thus, even from the first period, subjects who play the stag hunt game without either receiving a message from or sending one to an opponent behave differently depending on what

[13] The negative coefficients on the interaction between the costly message conditions and Message “2” indicate that the effect of receiving a message is weaker under costly messages than under costless messages.

[14] This occurred 40 percent of the time in RC-10, 63 percent in RC-100, 92 percent in UC-300, and (by construction) 100 percent of the time under No Messages. The no-messages case did not occur under Costless Messages, where every pair in Period 1 had at least one message, so we omit this condition from the model.

type of communication was possible, in a manner consistent with our predictions.

Figure 4 explores whether responsiveness to messages in the two Reasonably Costly message conditions varies across periods. The graphs show the frequency of action 2 choices across periods, following either receiving (thin solid line) or not receiving (thick solid line) a message. The graphs also show the frequency of message "2." In both conditions, subjects are slightly more likely to select action 2 when they receive a message of "2" from their opponent than when they do not, but the frequencies in both cases are quite high. The graphs also reveal little change in behavior over time.

D. Variation Across Time - Learning

One might worry that our appeal to forward induction as the principal explanation for the central tendency in our data relies on an undue faith in the subjects' introspective abilities. This would be especially true if we observed that the modal behavior of efficient play without messages only arose after repeated play. Subjects might, for example, initially use messages to coordinate on action 2 and then learn to sustain this outcome while dispensing with the use of messages. While this concern is plausible, the evidence suggests that it is unfounded.

First, in the treatments where messages are available and at most reasonably costly, we see no significant trends in the use of message 2. This is evident in Figure 4 and in the fact that the coefficient on period (and on period interacted with treatment) in model 2 of Table 4 is small and statistically insignificant.

Second, in the treatments where messages are available and at most reasonably costly, Figure 2 indicates that the frequency of action 2 is essentially constant over time. Notice that in model 2 of Table 5 the coefficient on Period representing the baseline No Message treatment is -0.046 and that the coefficient on Period X RC-10 representing the effect in RC-10 relative to the No Message baseline is 0.049. The net effect of 0.049 – 0.046 is not significantly different from zero. Similarly, the sum of coefficients on Period and on Period X RC-100 is close to zero. This is in sharp contrast to the treatments where messages are either unavailable (no messages) or prohibitively costly (UC-300), where we see significant declines in the frequency of action 2.[15] Thus, while there is clear evidence for learning without messages or with unreasonably costly

[15] The coefficient on Period X UC-300 is negative and significant indicating that the decrease over time in the frequency of choices of action 2 is more pronounced in the UC-300 treatment than in the baseline No Messages treatment.

messages, learning appears to play little or no role in determining action choices when messages are reasonably costly.

Third, as indicated in Figure 4, there is essentially no change over time in the frequency of action 2 conditional on receiving no message and hardly any change in the frequency of action 2 in response to receiving message 2.

Fourth, both the impact on the frequency of action 2 choices of making reasonably costly messages available and the fact that typically these messages are not used are already observed in period 1, as indicated in models 4 and 5 of Table 5. Note that when we pool the data from treatments RC-10 and RC-100 (which are not theoretically distinguished by the GW-FI analysis) the coefficient on the treatment effect in model 5, which uses only first period data and in which no messages were sent, is positive and significant at the 5% level (p=0.024). Thus, the effect is present from the first period on.

As one might expect, the forward induction prediction does not account for all behavior either in the first period or in subsequent periods. In a small but persistent fraction of observations subjects send messages in the RC-10 and RC-100 treatments. There is also some churning, with some subjects moving from forgoing messages in one period to sending messages in the next period and *vice versa*. For example, of the RC-10 (RC-100) subjects who achieved the efficient equilibrium in the first period, 26 (37) again sent no message in period 2 and 6 (5) sent message 2. Conversely, of the RC-10 (RC-100) subjects who achieved the efficient equilibrium in the second period, 11 (16) already got there tacitly in the first period, 7 (6) got there with one message and 2 (0) with two messages. Figure 1 shows that in the treatments with reasonably costly messages churning is confined to a subset of subjects; the modal behavior is to never send a message. Thus, while there may be individual instances of subjects learning to forgo messages, the modal pattern of behavior is established from the first period on and does not emerge over time as a result of learning.

E. Heterogeneity Across Sessions

Most of our prior analysis aggregates behavior across sessions, which may hide between-session heterogeneity. We present, in Figure 5, results from the individual sessions for each condition. The horizontal axis indicates the frequency of message "2" in a session, while the vertical axis indicates the frequency of action 2. The gridlines divide the graph into quadrants, three of which correspond to predicted message and action frequencies from our hypotheses (see Table 3):[16] low message frequency and high action 2 frequency under Reasonably Costly messages (H1), high message frequency and high action 2 frequency under Costless Messages (H2), low message frequency and low action 2 frequency under Unreasonably Costly (H3) or No Messages (H4). With few exceptions the sessions within a particular condition lie in the appropriate quadrant – the exceptions are: one RC-10 session had slightly more than 0.5 message frequency (0.51), one RC-100 session had a low action 2 frequency (0.35), and one session with No Messages obtained a high frequency of action 2 (0.85, see footnote 9). But the remaining 22 sessions all lie in the appropriate quadrant, providing strong support for our predictions. All but two (of 14) sessions with Reasonably Costly messages had both message frequencies below 0.44 and action 2 frequencies above 0.56, and five sessions in these conditions had both message frequencies below 0.04 and action 2 frequencies above 0.90 (these are the sessions clustered towards the top left of the graph). Meanwhile, no session with Unreasonably Costly messages obtained an action 2 frequency greater than 0.3. Thus, while there is some heterogeneity at the session level, the behavior in a large majority of sessions generally conforms to our predictions.

V. Discussion and Relation to the Literature

We present novel experimental results on the role of communication in resolving tension between risk and efficiency in strategic interactions. Our central observation is that access to pre-play communication favors efficient play in stag-hunt games even if communication is optional and moderately costly.[17] Surprisingly, agents tend to achieve the efficient outcome without exercising their communication option. This behavior can be rationalized using forward induction, as defined by Govindan and Wilson (2009).

[16] To account for possible noise in the data, our hypotheses stated predictions in terms of modal behavior. More precise predictions correspond to the corner in each quadrant where message and action frequencies are either 0 or 1.

[17] Two recent experimental papers explore different kinds of costly pre-play communication in coordination games. Manzini, Sadrieh and Vriend (2009) consider pre-play communication unrelated to game strategies – i.e., "smiles" that players can send to one another prior to playing the game. The use of smiles, though infrequent, slightly increases the frequency with which players select higher (more efficient) strategies, but this does not translate into better coordination because of the infrequency with which subjects use smiles and the small effect of messages. A treatment with costly smiles yields significantly reduced use of these messages (less than 1 percent of cases result in both players smiling), though the ambiguous benefit of costless smiles make it difficult to predict what should happen when costs are introduced. Fehr (2011) finds that players infrequently vote to impose a costly communication regime on all players, prior to merging two three-person groups playing a coordination game, resulting in coordination failure. This research suggests that people fail to properly anticipate the benefit of costly pre-play messages. This contrasts with our result from the two-player game in this paper, which suggests that players choose not to send messages because they are *unnecessary* when costly.

Much of the experimental literature on strategic risk-efficiency tradeoffs has focused on 2-player, 2-action stag-hunt games and their multi-player multi-action relatives, weak-link games (Bryant 1983).[18] For the stag-hunt game without communication, a stylized fact that emerges from the literature is that the risk-dominant outcome (Harsanyi and Selten, 1988) tends to be selected (Cooper et al., 1990 & 1992). Similarly, in weak-link games there is a strong tendency for efficient play to unravel in favor of players choosing secure strategies (Van Huyck et al., 1990). Our experiment provides further evidence for the selection of the risk-dominant outcome in stag-hunt games without communication, replicating the no-communication results of Cooper et al. (1990 & 1992).

A number of theoretical papers have put forward the case for pre-play communication with cheap-talk messages playing a role in equilibrium selection, including Farrell (1988), Kim and Sobel (1995), Farrell and Rabin (1996), Blume (1998) and Demichelis and Weibull (2008).[19] The evidence from the experimental literature suggests that mandatory universal pre-play communication with cheap-talk messages favors Pareto efficiency in stag-hunt games (Cooper et al., 1990 & 1992) and weak-link games (Blume and Ortmann, 2007). Our experimental results show that universal cheap talk continues to promote efficient play in stag-hunt games, even if message exchange is voluntary. Furthermore, when such voluntary messages are costless, they are regularly used.

Optional pre-play communication with costly messages has been addressed in the theoretical literature on money-burning games. Ben-Porath and Dekel (1992) made the remarkable observation that if a single player is given the opportunity to burn money prior to a game he may be able to induce his favorite equilibrium without having to exercise this option. Specifically, they show that that this is the unique outcome that remains after iterative deletion of weakly dominated strategies. Their result does not extend to multi-sided money-burning games. Hurkens (1996), however, shows that an analogous result does hold in this case if one uses Basu

[18] Weak-link game have been experimentally studied by for example Van Huyck et al. (1990), Weber et al. (2001), Weber (2006) and Brandts and Cooper (2006), and represent useful models of varied economic activity, such as investment or production under complementarities (Bryant, 1983; Hirschleifer, 1983; Knez and Camerer, 1994).

[19] For theoretical analyses of the effectiveness of unilateral vs. multilateral communication, see Ellingsen and Östling (2010). In experiments, Cooper et al (1992) find that two-sided communication is more efficiency enhancing than one-sided communication. Weber et al. (2001) and Chaudhuri et al. (2009) find varying effectiveness of limited forms of communication. Other experimental evidence provides instances in which one-way communication yields high levels of efficiency (Charness, 2000; Duffy and Feltovich, 2002; Brandts and Cooper, 2007) or even out-performs two-way communication (Burton et al., 2005).

and Weibull's (1991) minimal curb condition as the solution concept. We show that for the stag-hunt game studied by Cooper et al. (1992), among the pure-strategy equilibrium outcomes, forward induction as defined by Govindan and Wilson (2009) selects the one where efficiency is achieved without communication.

Forward induction captures the intuition that players make inferences about others' future behavior from their past behavior based on their rationality. The terminology was introduced by Kohlberg and Mertens (1986, p. 1029) who associated it with the following property of stable sets of equilibria: "A stable set contains a stable set of any game obtained by deletion of a strategy which is an inferior response in all the equilibria of the set." Van Damme (1989) provides an alternative definition of forward induction based on the extensive form of the game. Pearce's (1984) extensive-form rationalizability expresses the forward-induction implications of assuming rationality and common belief of rationality (Battgalli and Siniscalchi, 2002). Govindan and Wilson (2002) explicitly define forward induction in the tradition of Kohlberg and Mertens. For our experimental data, extensive-form rationalizability and the closely related iterative admissibility condition correctly predict that strictly dominated strategies will not be used but fail to narrow down the prediction to efficient play without message use. This tendency in our data toward playing efficiently while forgoing the use of costly messages is predicted by applying the forward-induction definition of Govindan and Wilson to the pure-strategy equilibrium outcomes of our game.

The prior experimental evidence on money-burning games and forward induction is mixed. Huck and Mueller (2005) study one-sided money-burning games and find support for the Ben-Porath and Dekel prediction when games are represented in extensive form, but not for the corresponding representation in strategic form. Brandts and Holt (1995) find support for forward induction predictions only in simple games, where forward induction is equivalent to elimination of dominated strategies. Cooper, DeJong, Forsythe and Ross (CDFR) (1994) find partial support for the forward-induction hypothesis in the battle of the sexes with an outside option. It is indeed the case that players benefit from having an outside option, but it is also true that the outside option is frequently chosen when the forward induction solution says that it should not be. While Van Huyck et al. (1993) find support for forward induction in experiments on auctioning the right to play median effort games, Cachon and Camerer's (1996) results suggest that some of this may be due instead to loss avoidance. Blume and Gneezy (2010) find evidence for "cognitive forward induction"; players who find it difficult to coordinate on a non-obvious focal point in a coordination game achieve better outcomes when they are conscripted into playing the game by someone who had an attractive outside option. On the other hand, similar to CDFR (1994), Blume and Gneezy find excessive use of the outside option. To the best of our knowledge, the results of the present paper are the first to lend (qualified) support to the forward-induction hypothesis in two-sided money burning games.

We also checked plausible alternative explanations for our experimental results, including level-k reasoning (Ellingsen and Östling, 2010) and quantal response equilibrium (McKelvey, R., and Palfrey, T., 1995; Anderson, S., Goeree, J., and Holt, C., 2001), and find that these cannot account for our results.[20] We can also rule out that subjects are simply selecting the efficient equilibrium, as there is no tendency toward efficient play when either messages are unavailable or are available but unreasonably costly. The fact that the results are clearly different between reasonably and unreasonably costly messages – subjects generally do not use messages in either case, but coordinate efficiently in the former but not in the latter – supports our argument that, consistent with forward induction, it is the inference subjects draw from unsent messages that is critical for our main result.

References

Anderson, S., Goeree, J., and Holt, C. (2001). "Minimum-Effort Coordination Games: Stochastic Potential and Logit Equilibrium," *Games and Economic Behavior*, 34(2), 177-199.

Asheim, G.B., and Dufwenberg, M. (2003). "Deductive Reasoning in Extensive Games," *The Economic Journal*, **113**, 305-325.

Basu, K., and Weibull, J. W. (1991). "Strategy Subsets Closed Under Rational Behavior," *Economics Letters,* 36, 141-146.

Battigalli, P., and Siniscalchi, M. (2002). "Strong Belief and Forward Induction Reasoning," *Journal of Economic Theory,* 106, 356-391.

Ben-Porath, E., and Dekel, E. (1992). "Signaling Future Actions and the Potential for Sacrifice," *Journal of Economic Theory*, 57, 36-51.

Blume, A. (1998). "Communication, Risk and Efficiency in Games," *Games and Economic Behavior,* 22, 171-202.

[20] The analysis is available from the authors upon request.

Blume A. and Gneezy, U. (2010). “Cognitive Forward Induction and Coordination without Common Knowledge: An Experimental Study,” *Games and Economic Behavior,* 68, 488-511.

Blume, A., and Ortmann, A. (2007). “The Effects of Costless Pre-play Communication: Experimental Evidence from Games with Pareto-ranked Equilibria,” *Journal of Economic Theory,* 132(1), 274-290.

Brandenburger, A., Friedenberg,A. and Keisler, J. (2008) “Admissibility in Games,” *Econometrica* 76, 307-352.

Brandts, J., and Cooper, D. (2006). “A Change Would Do You Good: An Experimental Study on How to Overcome Coordination Failure in Organizations,” *American Economic Review,* 93(1), 669-693.

Brandts, J., and Cooper, D. (2007). "It's What You Say, Not What You Pay: An Experimental Study of Manager-Employee Relationships in Overcoming Coordination Failure,” *Journal of the European Economic Association*, 5(6), 1223-1268.

Brandts, J. and Holt, C.A. (1995). “Limitations of Dominance and Forward Induction: Experimental Evidence,” *Economics Letters*, 49, 391-395.

Bryant, J. (1983). A simple rational-expectations Keynes-type model. *Quarterly Journal of Economics*, *98*, 525–529.

Burton, A., Loomes, G., and Sefton, M. (2005). “Communication and Efficiency in Coordination Game Experiments.” In Experimental and Behavioral Economics. Advances in Applied Microeconomics, vol. 13, ed. John Morgan, 63–86. Amsterdam: JAI Press.

Cachon, G.P., Camerer, C.F., (1996). “Loss-avoidance and forward induction in experimental coordination games,” *Quarterly Journal of Economics,* 111, 165–194.

Camerer, C.F. (2003). Behavioral Game Theory: Experiments in Strategic Interaction. Princeton University Press.

Charness, G. (2000). “Self-Serving Cheap Talk: A Test of Aumann’s Conjecture,” *Games and Economic Behavior,* 33(2), 177-194.

Chaudhuri, A., Schotter, A., and Sopher, B. (2009). “Talking ourselves to efficiency: coordination in inter-generational minimum-effort games with private, almost common and common knowledge of advice,” *Economic Journal*, *119*, 91–122.

Cooper, R., DeJong, D., Forsythe, R., and Ross, T. (1990) "Selection Criteria in Coordination

Games: Some Experimental Results," *American Economic Review*, 80, 218-33.

Cooper, R., DeJong, D., Forsythe, R., and Ross, T. (1992). "Communication in Coordination Games," *The Quarterly Journal of Economics*, 107(2), 739-771.

Cooper, R., DeJong, D.V., Forsythe, R., Ross, T.W., (1994). "Alternative institutions for resolving coordination problems: Experimental evidence on forward induction and preplay communication," In: Friedman, J.W. (Ed.), Problems of Coordination in Economic Activity. Kluwer Economic Publishers, Boston.

Demichelis, S., and Weibull, J.W. (2008). "Language, Meaning, and Games: A Model of Communication Coordination and Evolution," *American Economic Review*, 98(4), 1292-1311.

Devetag, G., and Ortmann, A. (2007). "When and Why? A Critical Review of Coordination Failure in the Laboratory," *Experimental Economics,* 10(3), 331-344.

Duffy, J., and Feltovich, N. (2002). "Do Actions Speak Louder Than Words? An Experimental Comparison of Observation and Cheap Talk," *Games and Economic Behavior*, 39(1), 1-27.

Ellingsen, T., and Östling, R. (2010). "When Does Communication Improve Coordination?," *American Economic Review,* 100(4), 1695-1724.

Farrell, J. (1988). "Communication, Coordination, and Nash Equilibrium," *Economics Letters*, 27, 209-214.

Farrell J., and Rabin M., (1996). "Cheap-Talk", Journal of Economic Perspectives, 10, 103-118.

Fehr, D. (2011). "The persistence of 'bad' precedents and the need for communication: A coordination experiment." Sonderforschungsbereich (SFB) 649 Discussion Paper 2011-039.

Fischbacher, U. (2007). "z-Tree: Zurich Toolbox for Ready-made Economic Experiments," *Experimental Economics,* 10(2), 171-178.

Govindan, S. and Wilson, R. (2009), "On Forward Induction," *Econometrica* 77, 1-28.

Harsanyi, J., and Selten, R. (1988). *A General Theory of Equilibrium Selection in Games*, Cambridge, MA: MIT Press.

Hirschleifer, J. (1983). From weakest-link to best-shot: The voluntary provision of public goods. *Public Choice*, *41*(3), 371–386.

Huck, S., and Mueller, W. (2005). "Burning Money and (Pseudo) First-Mover Advantages: An

Experimental Study on Forward Induction," *Games and Economic Behavior,* 51, 109-127.

Hurkens, S. (1996). "Multi-Sided Pre-Play Communication by Burning Money," *Journal of Economic Theory,* 69, 186-197.

Kalai, E. and Samet, D. (1984). "Persistent Equilibria," *International Journal of Game Theory*, 13, 129-144.

Kim, Y.-G., and Sobel, J. (1995) "An Evolutionary Approach to Pre-Play Communication," *Econometrica*, 63(5), 1181-1193.

Knez, M., and Camerer, C.F. (1994). "Creating Expectational Assets in the Laboratory: Coordination in 'Weakest- Link' Games," *Strategic Management Journal, Vol. 15, Special Issue: Competitive Organizational Behavior), pp. 101-119.*

Kohlberg, E., and Mertens, J. (1986). "On the Strategic Stability of Equilibria," *Econometrica,* 54, 1003-1037.

Kreps, D. and Wilson, R. (1982). "Sequential Equilibrium," *Econometrica* 50, 863-894.

Manzini, P., Sadrieh, A., and Vriend, N. J. (2009). "On smiles, winks and handshakes as coordination devices." *The Economic Journal*, 119, 826-854.

McKelvey, R., and Palfrey, T. (1995). "Quantal Response Equilibria for Normal Form Games," *Games and Economic Behavior,* 10(1), 6-38.

Pearce, D. G. (1984). "Strategic Behavior and the Problem of Perfection," *Econometrica* 52, 1029-1050.

Reny, P. J. (1992). "Backward Induction, Normal Form Perfection and Explicable Equilibria," *Econometrica* 60, 627-649.

van Damme, E. (1989). "Stable Equilibria and Forward Induction," *Journal of Economic Theory* 48**,** 476-496.

Van Huyck, J., Battalio, R., and Beil, R. (1990). Tacit coordination games, strategic uncertainty, and coordination failure. *American Economic Review*, *80*, 234–248.

Van Huyck, J., Battalio, R., Beil, R., (1993). "Asset Markets as an Equilibrium Selection Mechanism: Coordination Failure, Game Form Auctions, and Forward Induction," *Games and Economic Behavior*, 5, 485–504.

Weber, R. (2006). "Managing Growth to Achieve Efficient Coordination in Large Groups," *American Economic Review*, 96(1), 114–126.

Weber, R., Camerer, C., Rottenstreich, Y., and Knez, M. (2001). "The Illusion of Leadership: Misattribution of Cause in Coordination Games," *Organizational Science,* 12(5), 582-598.

Table 3: Experimental Conditions

Communication Condition	Message Cost (in ECU)	Prediction (message "2", action)
Costless Messages	c = 0	message, action 2 (H2)
Reasonably Costly Messages (RC-10)	c = 10	no message, action 2 (H1)
Reasonably Costly Messages (RC-100)	c = 100	
Unreasonably Costly Messages (UC-300)	c = 300	no message, action 1 (H3)
No Messages	-	action 1 (H4)

Table 4: Random-effects Probit Regressions of Message "2" Use

Dependent variable: Subject sent message "2"	All periods		Period 1
	(1)	(2)	(3)
Reasonably Costly Messages (RC-10)	-4.384*** (0.404)	-4.410*** (0.440)	-1.372*** (0.313)
Reasonably Costly Messages (RC-100)	-5.165*** (0.400)	-5.218*** (0.438)	-2.035*** (0.329)
Unreasonably Costly Messages (UC-300)	-5.891*** (0.419)	-5.777*** (0.464)	-3.021*** (0.491)
Period		0.006 (0.008)	
Period X Reasonably Costly Messages (RC-10)		0.001 (0.009)	
Period X Reasonably Costly Messages (RC-100)		0.002 (0.009)	
Period X Unreasonably Costly Messages (UC-300)		-0.006 (0.010)	
Constant	2.771*** (0.323)	2.662*** (0.361)	0.967*** (0.272)
Observations	8800	8800	220
Number of subjects	220	220	220
Log Likelihood	-1884.94	-1880.18	-92.13

All models include data from all conditions with messages; models 1 and 2 include subject random effects
Standard errors in parentheses; * - p < 0.1; ** - p < 0.05; *** - p < 0.01

Table 5: Probit Regressions of Action Choice 2 in Stag-Hunt Subgame

Dependent variable: Subject chose action 2	All periods (1)	All periods (2)	All periods (3)	Period 1 (4)	Period 1 & no messages (5)
Costless Messages	2.346*** (0.390)	2.115*** (0.450)	0.746 (0.453)	1.198*** (0.387)	
Reasonably Costly Messages (RC-10)	2.132*** (0.328)	1.261*** (0.368)	1.997*** (0.367)	0.708** (0.284)	0.590* (0.345)
Reasonably Costly Messages (RC-100)	1.735*** (0.327)	0.649* (0.366)	1.602*** (0.320)	0.758*** (0.286)	0.664** (0.310)
Unreasonably Costly Messages (UC-300)	-0.353 (0.341)	-0.003 (0.383)	-0.480 (0.381)	0.067 (0.290)	0.136 (0.295)
Period		-0.046*** (0.005)			
Period X Costless Messages		0.020** (0.008)			
Period X RC-10		0.049*** (0.006)			
Period X RC-100		0.059*** (0.006)			
Period X UC-300		-0.023*** (0.007)			
Received Message “2” (Costless Messages)			2.366*** (0.198)		
Received Message “2” X RC-10			-0.848*** (0.233)		
Received Message “2” X RC-100			-0.173 (0.250)		
Received Message “2” X UC-300			-0.745*** (0.249)		
Constant	-0.415 (0.272)	0.456 (0.308)	-0.435 (0.304)	0.084 (0.229)	0.084 (0.229)
Observations	10000	10000	10000	250	148
Number of subjects	250	250	250	250	148
Log Likelihood	-3500.49	-3233.64	-3096.57	-136.18	-91.24

Models 1 through 4 include data from all conditions; model 5 omits Costless Messages; models 1 through 3 include subject random effects.
Standard errors in parentheses; * - p < 0.1; ** - p < 0.05; *** - p < 0.01

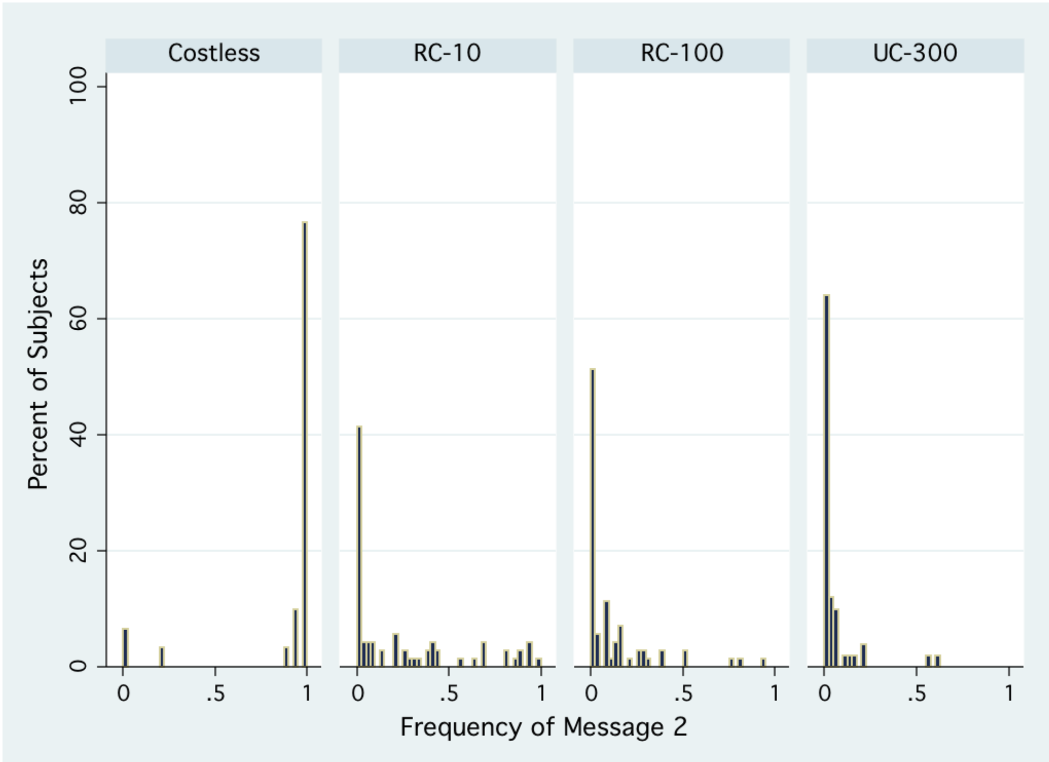

Figure 1: Distribution of Individual Frequency of Message Use by Condition

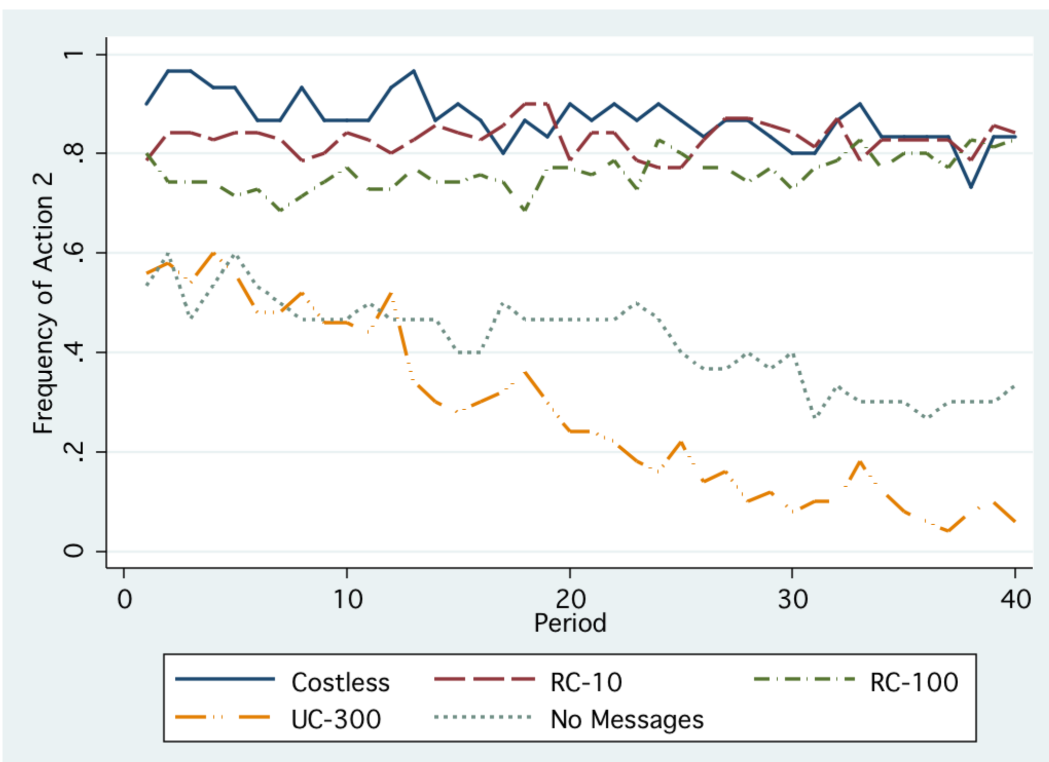

Figure 2: Action Choice over Time

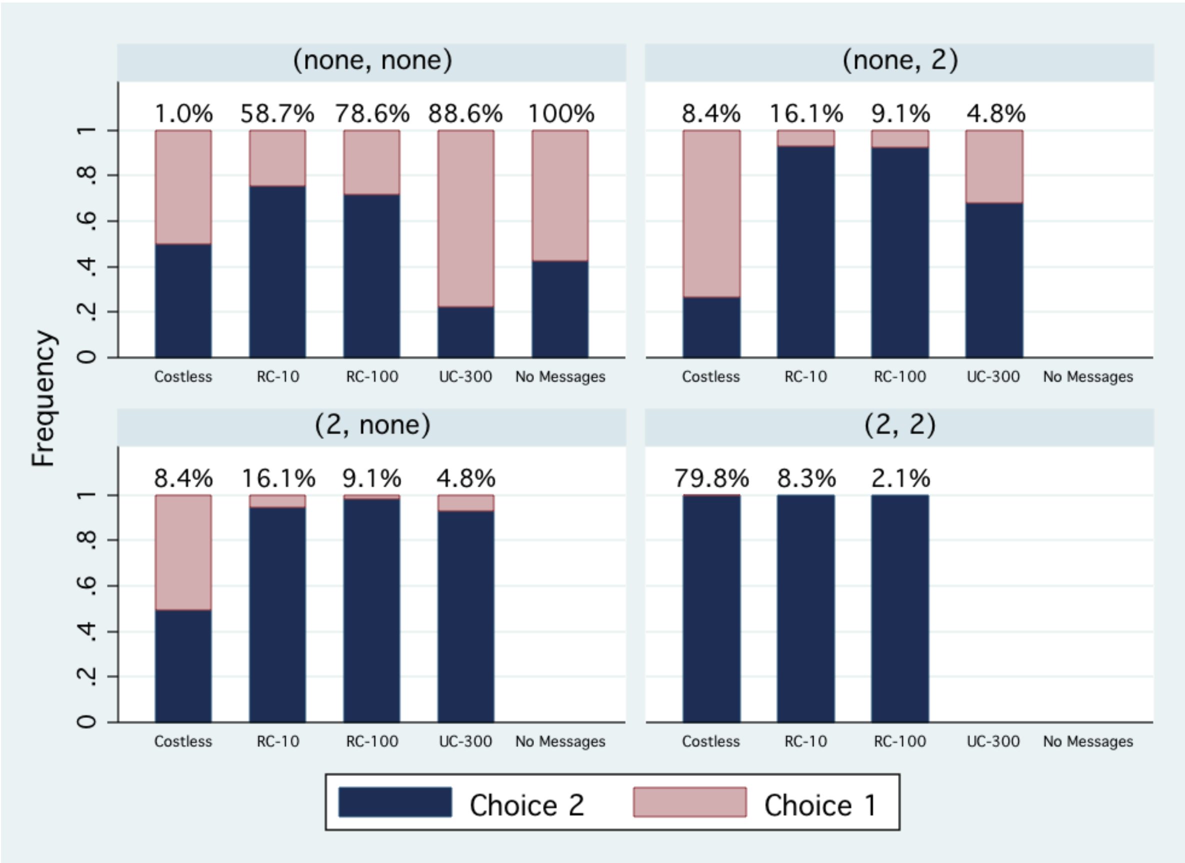

Figure 3: Choices Conditional on (Message Sent, Message Received)

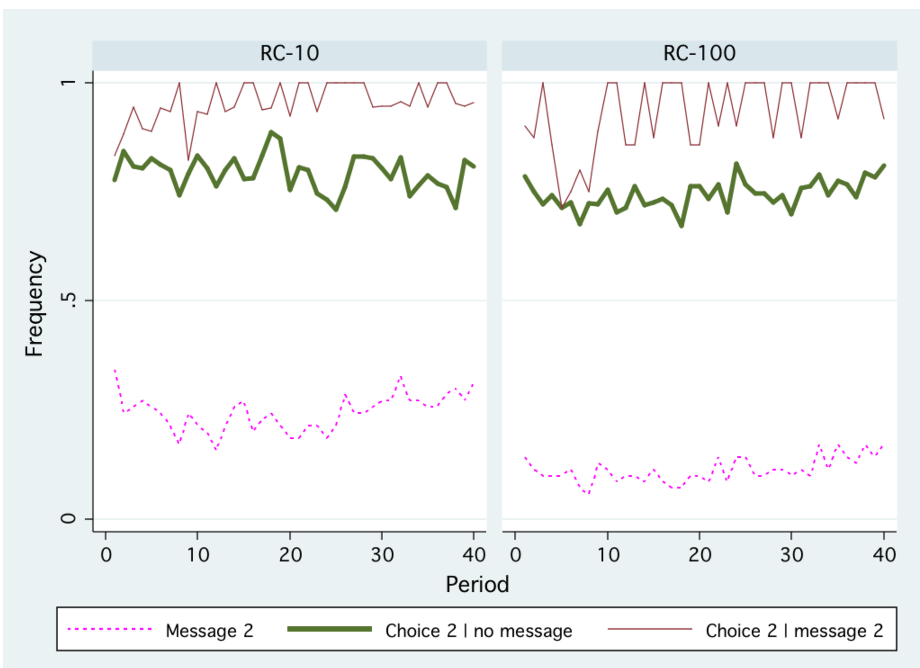

Figure 4: Choices Conditional on Message Received over Time

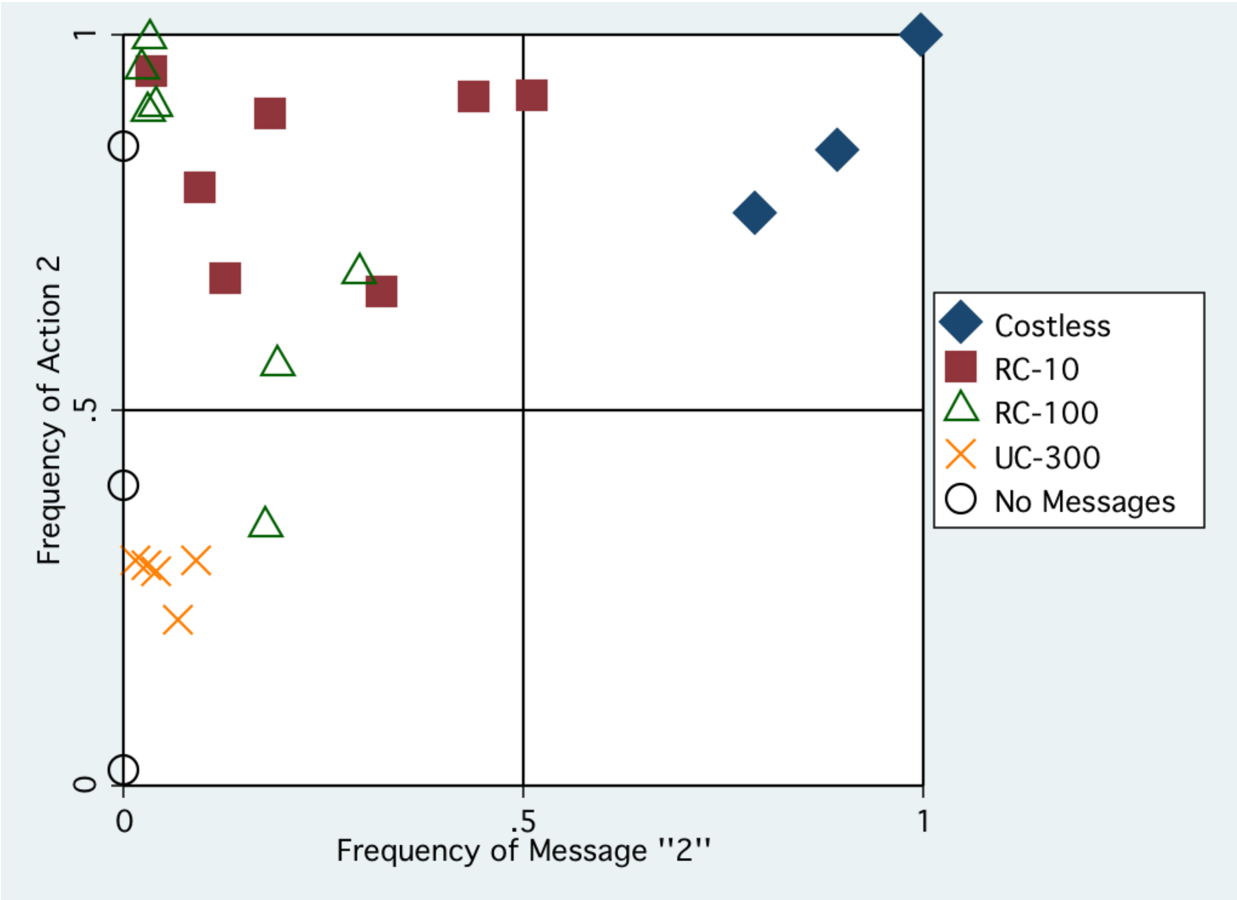

Figure 5: Message and Action Frequencies by Session

Appendix: Instructions (RC-10 Condition)

General Information:

This is an experiment in decision-making. This study has been reviewed by the University of Pittsburgh's Institutional Review Board and been given expedited approval.

Thank you for attending the experiment. The purpose of this session is to study how people make decisions. **If you have any questions during the experiment, please raise your hand and wait for an experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment.** Participants intentionally violating the rules may be asked to leave the experiment and may not be paid.

You will be paid for your participation. You will receive a $2 participation fee in addition to the money you make from the game that we will describe shortly. All payoffs during the experiment are denominated in an artificial currency, experimental currency units (ECU). At the end of the experiment, ECU will be converted to cash at the rate of $1 per 2500 ECU. Upon completion of the experiment, your earnings will be converted to dollars and you will be paid privately, in cash. The exact amount you receive will be determined during the experiment and will depend on your decisions and the decisions of other participants.

Please click "Continue" when you are ready.
If you have a question, please raise your hand and wait for the experimenter.

Continue

Playing the Game:

This experiment consists of 40 periods. In each period, you will be randomly matched with another player. You will never know this player's identity and he or she will never know your identity.

You and this other player will each make a decision based on the table below. The amounts shown in the table will reflect the possible payments you might receive. This payment depends on the choice that you make and the choice that the other player makes.

Each participant will choose strategy 1 or strategy 2. You may change your choices as often as you like, but once you click on "OK" your choice will be final. Note that when you make your decision you will not know the choice of the other player.

After you and the other player have made your decisions, the outcome of the period will be revealed to you and the other player. You will see both your strategy choice and the choice of the other player and your earnings for that period. When you are ready to continue, the computer will randomly match you with another participant and you will play the game again.

Payoff Table

		Other Player's Choice	
		1	2
Your Choice	1	Your Payoff: 800 Other's Payoff: 800	Your Payoff: 800 Other's Payoff: 0
	2	Your Payoff: 0 Other's Payoff: 800	Your Payoff: 1000 Other's Payoff: 1000

Please click "Continue" after you have read the above carefully.
If you have a question, please raise your hand and wait for the experimenter.

Continue

Payoff Quiz

Before we begin the experiment, we would like you to answer a few questions to make sure that everyone understands the task. Everyone will answer the same questions before we proceed. Once you answer the questions below, please click "Continue." If you have answered any questions incorrectly, you will be asked to try those questions again. Please raise your hand if you are having trouble answering any of the questions.

Payoff Table

		Other Player's Choice	
		1	2
Your Choice	1	Your Payoff: 800 Other's Payoff: 800	Your Payoff: 800 Other's Payoff: 0
	2	Your Payoff: 0 Other's Payoff: 800	Your Payoff: 1000 Other's Payoff: 1000

1) Suppose you choose 1 and the other player chooses 1.

Your payoff in ECU:

Other player's payoff in ECU:

2) Suppose you choose 1 and the other player chooses 2.

Your payoff in ECU:

Other player's payoff in ECU:

3) Suppose you choose 2 and the other player chooses 1.

Your payoff in ECU:

Other player's payoff in ECU:

4) Suppose you choose 2 and the other player chooses 2.

Your payoff in ECU:

Other player's payoff in ECU:

5) Each period, I will be randomly matched with a different player than in the previous period.

TRUE
FALSE

Please click "Continue" when you are ready.

Continue

Sending a Message:

Because the other player's choice partly determines your payoff, you may wish to send a message to the other player. If you send a message, you may choose message "1" or "2" to indicate the choice that you intend to make. If you choose to send a message, you will incur a cost of 10 ECU. Sending a message does not commit you to any particular choice. That is, you are not required to choose the action that corresponds to the message you send.

You may also choose not to send a message. If you do not send a message, you will not pay 10 ECU.

The other player will also have the same option of sending a message to you. If the other player chooses to send a message, he or she will pay 10 ECU.

Receiving a message from the other player is costless. That is, even if you choose not to send a message you will receive the other player's message if he or she sent one.

After you both decide whether to send messages and after you both observe any message sent by the other player, you will make choices in the task.

Please click "Continue" when you are ready.
If you have a question, please raise your hand and wait for the experimenter.

Continue